~~Specification~~

~~Method for Producing a Strong Bond between Two Layers of a Multilayer System, and Multilayer System~~**METHOD FOR PRODUCING A STRONG BOND BETWEEN TWO LAYERS OF A MULTILAYER SYSTEM, AND MULTILAYER SYSTEM**

PRIORITY INFORMATION

This patent application claims priority from German Application No. 102 37 013.3 filed August 13, 2002 and International Application No. PCT/EP2003/008913 filed August 12, 2003, which are hereby incorporated by reference.

BACKGROUND OF THE INVENTION

The invention relates in general to semiconductors and in particular to a method for securely bonding together first and second functional layers of semiconductors.~~producing a strong bond between two layers of a multilayer system and to a multilayer system of at least two layers.~~

Multilayer systems comprise ~~are built up from~~ at least two mutually adhering layers and serve, for example, as sensors for detecting substances such as ~~for example~~ gases. Those layers that detect the substance are typically referred to as functional layers.

A ~~first severe~~ disadvantage of such functional layers is that they may ~~do~~ not adhere together with sufficiently high strength. For this reason, an additional intermediate ~~third~~ layer yielding a greater adhesive action may be inserted ~~is necessary~~ between the two functional

layers.~~,~~ However, the intermediate ~~which third~~ layer~~,~~ may have the ~~however, brings about a second~~ disadvantage in that this ~~the third~~ layer may ~~considerably~~ diminishes the functionality of the functional layers.

In the case of a hydrogen sensor, for example, adequate measuring accuracy requires the cleanest possible interface~~boundary surface~~ between ~~the~~ one functional layer made of, for example, palladium and another ~~the other~~ functional layer made of, for example, silicon nitrite. However, ~~Unfortunately,~~ these two materials comprising the functional layers generally do not adhere together relatively well.~~at all,~~ As a result, disposed ~~so that~~ between these two functional layers is usually an intermediate ~~there must be a third~~ layer ~~acting as a sort of cement,~~ which ~~third layer~~ adheres relatively well ~~both~~ to both ~~the one and to the other~~ functional layers. ~~Suitable for the stated purpose in this example is n~~Nickel may be used as the intermediate layer to adhere the two functional layers of the hydrogen sensor together. ~~, which, h~~However, the use of nickel typically ~~greatly~~ impairs ~~or cancels entirely~~ the functionality of a hydrogen sensor to some degree.

Thus, in general, ~~On the one hand,~~ the functional layers should adhere strongly together, yet ~~but on the other hand,~~ their functionality should ~~must~~ not be impaired.

As a result of this tradeoff, ~~For this reason,~~ the method described in German patent DE 42 40 996 C1 is not generally applicable. Therein, ~~Herein~~ two layers are bonded using a layer of adhesive applied therebetween, which is passed through in pointwise fashion by islands of fast-setting hot-melt adhesive. These ~~hot-melt~~ adhesive islands ~~have the function of~~ fixing the layers with respect to one another until the layer of adhesive applied in a large-area manner ~~fashion~~ takes effect. With macroscopically thick layers of adhesive, this method is well-suited to the bonding of circuit arrangements to a circuit board, but less suitable~~e~~ to the use of functional

layers, because the thick layers of adhesive may ~~here~~ impair the functionality of the components. Further, ~~What is more,~~ this method presupposes that a material is known with which a firm bond can be produced between the various layers.

German patent application ~~Furthermore, in~~ DE 28 21 303 B1 ~~there is~~ describes~~d~~ a method for bonding an insulating substrate to a metal coating, where~~in~~ the insulating substrate has a certain ~~special~~ chemical composition. The~~is~~ chemical composition makes possible a selective etching operation by which depressions are made in the insulating substrate, thereby increasing ~~and thus~~ its surface area ~~is increased~~. Afterward, a metal coating is deposited on the substrate in a currentless manner~~fashion,~~. The ~~which~~ metal coating enters into a stronger bond with the substrate because of the ~~basins in, or the~~ increased surface area of~~,~~ the substrate. This method has the disadvantage that it is~~can be~~ utilized with only those ~~applied only for~~ layer systems in which the requisite adhesive force can be achieved through an increase in the adhesion area. If~~,~~ ~~however,~~ the materials of the two layers do not generally adhere to one another, or if the requisite adhesive force is not attained even after the increase in the surface area, then this method does not achieve ~~lead to~~ the desired success.

Similarly, the method described in German patent application ~~of~~ DE 197 18 177 A1 utilizes an increase in the surface area of a substrate layer to improve the adhesion between this substrate and a second layer to be applied. Therein ~~Here~~ the substrate surface area is increased by first applying opaque particles to the substrate surface, ~~by~~ which ~~a~~ masks~~ing~~ ~~of~~ the substrate surface~~ is effected~~. Next, material is stripped off in the unmasked regions of the substrate surface, for example by ~~treatment with~~ a laser.~~;~~ This ~~which~~ has the effect of roughening the substrate surface. After the masked particles are removed, the second layer is applied to the substrate surface and, because of the increased adhesion area, a stronger bond between the two layers

results. ~~In comparison with the method described above, t~~This method ~~one~~ has the advantage that when the material-stripping light is obliquely incident, webs remain on the substrate surface, which webs narrow toward the substrate surface. If the second layer is subsequently applied to the substrate, a type ~~sort~~ of keying interlocking results between the substrate and the second layer.~~,~~ This results in ~~which has the consequence of~~ enhanced adhesion and, in particular, bonding between two layers that may ~~would~~ otherwise not adhere to one another. Due to ~~Because of~~ features of the method, the webs serving as anchoring elements may be ~~are~~ made of the same material as the substrate. As a consequence, if the layer to be applied adheres poorly or not at all to the substrate, it may be ~~is~~ necessary to provide a relatively high number ~~density~~ of wedge-shaped webs or anchoring elements ~~in order~~ to ensure adequate ~~-yielding~~[1] adhesion between the layers to be bonded. If the webs are not fashioned in wedge shape, a strong adhesive bonding of the layers may ~~is~~ not be possible ~~in this case~~.

What is needed is a method for producing a relatively strong bond between two functional layers of a semiconductor while at the same time allowing for a relatively high degree of functionality of the layers. ~~Now it is not, as would be anticipated and is usually conventional, a goal of the invention to find the optimal compromise between adhesion and functionality, but rather to achieve a combination of both maximum adhesion and optimum functionality.~~

SUMMARY OF THE INVENTION

~~In terms of method, this goal is achieved with the features cited in Claim 1 in that anchoring elements made up of a different material from the layers to be bonded are embedded in at least one of the two layers.~~

~~1 The word *ausweichende* (= yielding) in the original may be an error for *ausreichende* (= adequate). —Translator.~~

~~In terms of device, this goal is achieved with the features cited in Claim 16 in that embedded in at least one of the two layers are anchoring elements made up of a different material from the two layers to be bonded.~~

~~The invention provides for embedding, in at least one of the two poorly mutually adhering layers, anchoring elements fabricated from a different material from the layers to be bonded.~~

A multilayer semiconductor includes first and second functional layers. ~~In an exemplary embodiment of the invention, a~~A third or intermediate layer is disposed between the first and second functional layers and ~~that~~ adheres relatively well to the first and second layers yet has relatively little or no detrimental effect on ~~but scarcely impairs~~ the functionality of the first and second layers. The third layer is ~~is further to be~~ applied to the ~~a~~ first layer. ~~The a~~Anchoring elements ~~provided according to the invention~~ are provided which are partly embedded in the third layer, and the second layer is secured ~~applied~~ to the third layer by the anchoring elements. This structure ~~practice~~ yields good adhesion between ~~of~~ the three layers, because the third layer adheres relatively well to the first ~~bottom~~ layer and ~~because~~ the third layer and the second layer are mechanically ~~strongly~~ bonded together relatively strongly by the anchoring elements.

In a ~~further exemplary embodiment, in a first step of the~~ method for binding together the first and second functional layers, to the ~~a~~ first layer ~~there~~ is applied, at least partially, a third layer~~,~~ in which a plurality of holes are formed~~made~~. The holes can be formed ~~made~~ in the third layer by, for example, an etching process or a photoetching process. ~~Next, t~~The holes may be ~~are~~ filled with an adhesive compound. Excess adhesive compound issuing from the holes is removed, for example by etching. ~~away. In a further step of the method, t~~The third layer may then be ~~is~~ stripped down to a predetermined ~~specifiable minimum~~ thickness, for example by an

etching process or a photoetching process. After etching the third layer, ~~At the end of this process,~~ anchoring elements formed from the adhesive compound protrude from the third layer. ~~Now t~~The second layer may then be ~~is~~ applied to the third layer~~.~~ after which ~~T~~the anchoring elements ~~formed from the adhesive compound~~ are ~~now~~ embedded ~~both~~ in both the third layer and ~~in~~ the second layer.~~,~~ The result is ~~so~~ that the second layer is securely ~~strongly~~ bonded to the third layer.

The holes in the third layer and also ~~thus~~ the anchoring elements formed from the adhesive compound can be cylindrical in shape. ~~Better anchoring is achieved, h~~However, a relatively stronger degree of anchoring can be achieved if the cross-sectional area of a hole and a corresponding ~~thus also of an~~ anchoring element ~~formed from the adhesive compound~~ increases or decreases from one end to the other end (e.g., tapered). For example, ~~T~~the cross-sectional area of the hole and of the anchoring element may ~~preferably~~ increases from the third layer end to the second layer end.~~,~~ The result is ~~so~~ that the anchoring elements have a conical or double conical shape, which ~~. This shaping yields an~~ mechanically interlocks~~ing~~ ~~of~~ the anchoring elements with the second layer. This is advantageous ~~particularly~~ when the adhesive compound does not adhere to the second layer, so that ~~no~~ bonding of the second and third layers may not be ~~would be~~ possible without interlocking.

~~With this method,~~ The two functional layers can be bonded together in various ~~three distinct~~ ways. For example, ~~If~~ if the second ~~layer~~ and ~~the~~ third layers are the ~~represent~~ functional layers, then the third layer can be ~~is~~ etched back ~~only~~ to the extent ~~that~~ this layer retains a thickness adequate for the functional layer. The first layer in this example is ~~case serves only as~~ a substrate~~,~~ that may ~~which can~~ serve, for example, if the holes are made in the third layer by an etching process, to stop the etching process as soon as the holes pass through the third layer from

the top of the third layer to the bottom. Also ~~But~~ if~~, besides,~~ the adhesive compound forming the anchoring elements adheres not to the third layer but to the first layer, then the anchoring elements adhering to the first layer and embedded in the second layer create a bond between the first layer and the second layer.~~,~~ This also ~~which~~ simultaneously results in ~~brings about~~ a strong bond between the third layer~~,~~ ~~which lies therebetween and acts as a functional layer,~~ and the ~~other functional layer, that is, the~~ second layer. ~~If, o~~On the other hand, if the material comprising the ~~of which the~~ anchoring elements ~~are made~~ adheres ~~in~~ adequately ~~fashion~~ to the third layer, then ~~it is not necessary for~~ the holes may not ~~to~~ pass through the~~is~~ third layer. As such, the holes for example can be of ~~Thus for example they can be fashioned in~~ conical shape. In this case, to the extent that the first layer is not required for stopping any etching process, the first layer may not be needed.~~it can in principle be dispensed with.~~

~~Now i~~If the first ~~layer~~ and ~~the~~ second layers comprise ~~form~~ the functional layers ~~system~~ and the material used for the anchoring elements adheres adequately ~~well~~ to the first layer, then the third layer can be completely removed after the holes have been filled with the adhesive compound. The first layer and the second layer are then bonded together by the anchoring elements without the ~~an interfering~~ intermediate third layer.

Also, if ~~If, again,~~ the first ~~layer~~ and ~~the~~ second layers comprise ~~represent~~ the functional layers and the material used for the anchoring elements adheres to neither of these two layers ~~to be bonded~~, then the third layer may comprise ~~is formed from~~ a material that enters into a strong bond both with the first layer and with the anchoring elements. After the anchoring elements have been formed, the third layer may be ~~is subsequently~~ etched back ~~only~~ to a predetermined ~~minimum~~ thickness depending on ~~given by~~ the required bond strength. The anchoring elements may be formed ~~are fashioned~~ such that their cross-sectional area decreases toward the first layer

such~~o~~ that, with the use of the ~~above-mentioned~~ interlocking effect, a strong bond is formed ~~ensured~~ between the anchoring elements or the third layer and the second layer, and thus also between the second layer and the first layer.

Also, ~~In a further exemplary embodiment of the invention,~~ there may be ~~is~~ a region free of the third layer, in which region the first ~~layer~~ and ~~the~~ second functional layers~~, which represent the functional layers,~~ directly adjoin one another. In this example, the third layer and corresponding anchoring elements may be located outside of this free region. As such, ~~The functionality is not impaired in the slightest in this region, while~~ the anchoring elements ~~provided~~ located outside the free region provide for ~~yield~~ good adhesion of all of the layers throughout.

~~For t~~The third layer may comprise ~~there is preferably~~ a material that ~~on the one hand~~ enters into a strong physical or chemical bond with the ~~one layer (i.e.,~~ the first layer or the second layer~~)~~ but ~~on the other hand~~ may impair~~s~~ the functionality of the two layers to a relatively small degree~~only slightly~~. Along with mechanical anchoring, the selection of the material for the anchoring elements can also increase ~~additionally boost~~ the adhesion of the second functional layer.

A dielectric is ~~particularly~~ suitable for the third layer. The conical shape of the anchoring elements is achieved for example with the aid of texturing methods that give well-defined weight to anisotropic and isotropic texturing.

The method may be used ~~according to the invention is suitable~~ for example for fabricating sensors comprising ~~made up of~~ a plurality of layers, but it is not limited as such. ~~by no means confined to this application.~~ Conductive layer bonds with strong adhesion may ~~can equally well~~ be produced, such as for example bond pads for ~~in the case of~~ semiconductors. Bond pads are ~~most~~ commonly fabricated from aluminum, and as such,~~.~~ ~~In the case of bond pads made of~~

~~aluminum,~~ the temperature in subsequent manufacturing process steps typically does ~~must~~ not exceed ~~a value of~~ 400 °C. This is particularly applicable in the case of methods for manufacturing semiconductor sensor chips. The method ~~present invention~~ is not, however, limited ~~restricted~~ to the use of bond pads made from aluminum. Alternative materials may be utilized ~~are conceivable~~.

~~The invention will be described and explained in greater detail with reference to the drawings, in which:~~ These and other objects, features and advantages of the present invention will become more apparent in light of the following detailed description of preferred embodiments thereof, as illustrated in the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG.~~igure~~ 1 is a cross-sectional illustration of ~~depicts~~ a first functional layer and a dielectric layer joined together;~~and a third layer formed from a dielectric;~~

FIG.~~igure~~ 2 is a cross-sectional illustration of ~~depicts~~ the first functional layer and ~~the~~ dielectric layer of FIG. 1, where the dielectric layer has ~~with pierced~~ holes formed therein;

FIG.~~igure~~ 3 is a cross-sectional illustration of ~~depicts~~ the first functional layer and the dielectric layer of FIG. 2, where the ~~whose~~ holes have been filled with adhesive compound;

FIG.~~igure~~ 4 is a cross-sectional illustration of ~~depicts~~ the first functional layer and the dielectric layer of FIG. 3 with the holes filled with adhesive compound, where excess adhesive compound has~~ving~~ been removed;

FIG.~~igure~~ 5 is a cross-sectional illustration of ~~depicts~~ the first functional layer~~,~~ and the dielectric layer of FIG. 4 with a portion of the dielectric layer etched away thereby forming ~~stripped to a minimum thickness, with~~ anchoring elements ~~formed~~ from the adhesive compound;

FIG.~~igure~~ 6 is a cross-sectional illustration of ~~depicts~~ the first functional layer~~,~~ and the dielectric layer of FIG. 5, also having a second functional layer~~,~~ and anchoring elements ~~anchoring~~ interlocking the dielectric layer and the second functional layer together;

FIG.~~igure~~ 7 is a cross-sectional illustration of ~~depicts~~ a multilayer semiconductor ~~system~~ having a functional region with no dielectric; and

FIG.~~igure~~ 8 is a cross-sectional illustration of ~~depicts~~ a multilayer semiconductor ~~system~~ having cylindrical anchoring elements.

DETAILED DESCRIPTION OF THE INVENTION

~~The steps of the method of one exemplary embodiment of the method according to the invention will now be described with reference to Figures 1 to 6.~~

Referring to ~~In the first step of the method, illustrated in~~ FIG.~~igure~~ 1, a dielectric layer 1~~, which here represents the third layer,~~ is applied to a first functional layer 2.

~~In the second step of the method, as is depicted~~ As illustrated in FIG.~~igure~~ 2, a plurality of holes 3, for example ~~preferably~~ in conical or double conical shape, are formed ~~pierced~~ in the~~to~~ dielectric layer 1. The ~~H~~holes 3 are formed~~pierced into dielectric 1 by~~, for example, by an etching process or a photoetching process.

~~In the third step of the method, illustrated i~~In FIG.~~igure~~ 3, the holes 3 are filled with an adhesive compound 4. Excess adhesive compound 5 issuing from holes 3 is removed, for example, by an etching process.

FIG.~~igure~~ 4 illustrates the ~~depicts~~ functional layer 2~~,~~ and the dielectric layer 1 with the ~~adhering to it having~~ holes 3 filled with adhesive compound 4, and after any excess adhesive compound 5 has been etched away.

Referring to FIG. 5, the ~~In the next, fifth, step of the method,~~ dielectric layer 1 undergoes an ~~is stripped down to a minimum thickness,~~ for example by an etching ~~process~~ or ~~a~~ photoetching process to expose ~~. A~~anchoring elements 9 formed from the adhesive compound 4~~. antherefore have their upper part protruding from dielectric 1. Functional layer 2 and dielectric 1 adhering to it and having protruding anchoring elements 9 are depicted in Figure 5.~~

~~Finally, in a sixth step of the method, the last step of the method,~~ In FIG. 6, a second functional layer 6 is applied to the dielectric layer 1. As a result, the ~~A~~anchoring elements 9 are ~~now strongly~~ embedded in both the dielectric layer 1 and the second functional layer 6, thereby ~~and therefore~~ bonding the second functional layer 6 relatively strongly to the dielectric layer 1. ~~This complete arrangement according to the invention is shown in Figure 6.~~

A dielectric material is ~~especially~~ suitable as this third layer or intermediate ~~a third~~ layer 1, because such material typically ~~it~~ does not impair the functionality of the functional layers 2, 6.

Referring to ~~A further exemplary embodiment of the invention is shown in~~ FIG.~~igure~~ 7, ~~.~~ ~~This exemplary embodiment~~ the multilayer semiconductor illustrated there differs from that illustrated ~~depicted~~ in FIG.~~igure~~ 6 in that there is a region 8 that is free of the dielectric layer 1. The ~~F~~first functional layer 2 and the second functional layer 6 directly adjoin one another in this region 8. As such, a higher degree of ~~For this reason, the maximum~~ functionality may be ~~is~~ achieved in the region 8 without any loss of adhesion. The ~~D~~dielectric layer 1 and the anchoring elements 9 formed from adhesive compound 4, which are embedded both in the dielectric layer 1 and in the second functional layer 6, are arranged next to the region 8 on both sides thereof, as illustrated in FIG. 7.

~~The exemplary embodiment of the invention illustrated in Figure 7 shows clearly that maximum functionality is combined with maximum adhesion. A further exemplary embodiment of the invention is depicted in Figure 8.~~

Referring to FIG. 8, the ~~Applied to first functional layer 2 is~~ dielectric layer 1~~,~~ is applied to the first functional layer 2, and the ~~to which~~ second functional layer 6 is adjacent the dielectric layer 1. The ~~A~~anchoring elements 19 formed from the adhesive compound 4 are embedded both in the dielectric layer 1 and in the second functional layer 6. The ~~A~~anchoring elements 19 are cylindrical in shape and as such may ~~therefore have the advantage that they can~~ be produced more easily than conically shaped anchoring elements 19. However, ~~T~~the degree of interlocking achieved with the cylindrical anchoring elements 19 may ~~is~~ not be ~~, however,~~ as strong as ~~is effected~~ with the conically shaped anchoring elements.

As discussed hereinabove, the teachings herein may be suitable, without limitation, for ~~invention is suitable for~~ multilayer sensors and for conductive layer bonds in semiconductor technology~~, but is by no means restricted to these application fields~~.

In semiconductor technology, bond pads can be fabricated similar to the multilayer semiconductors of FIGs. 1-8 ~~with the method according to the invention~~ at process temperatures ~~lying~~ above 400°C. The filling compound for forming the anchoring elements may comprise ~~is~~ the element tungsten. The conductive layers, which correspond to the functional layers, are fabricated for example from a noble metal.

Values between 100 and 1000 nm may be ~~have proven favorable as~~ suitable dimensions for the diameter and spacing of the anchoring elements. The layer thicknesses may also be ~~likewise lie~~ between 100 and 1000 nm. The anchoring elements may protrude some 20 to 500 nm from the top of the dielectric layer.

~~The method according to the invention is generally suitable for the production of multilayer systems whose layers do not adhere together well, but without the disadvantage of requiring third layers that disadvantageously restrict the functionality of the multilayer system. The invention makes it possible to combine maximum functionality with maximum adhesive action.~~

Although the present invention has been shown and described with respect to several preferred embodiments thereof, various changes, omissions and additions to the form and detail thereof, may be made therein, without departing from the spirit and scope of the invention.

What is claimed is:~~List of Reference Characters~~

~~1 Dielectric as third layer~~

~~2 First functional layer~~

~~3 Hole~~

~~4 Adhesive compound~~

~~5 Excess adhesive compound~~

~~6 Second functional layer~~

~~7 Clean boundary layer between first functional layer and second functional layer~~

~~8 Functional region free of dielectric and anchoring elements~~

~~9 Anchoring el~~